Intensive Eye Gaze Training for AAC Access: A Case Study

BY

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Submitted to the graduate degree program in Speech, Language, Hearing and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

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Date Defended: April 28, 2016

The Thesis Committee for Corinne Walker certifies that this is the approved version of the following thesis:

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Date approved: May 6, 2016

Abstract

This was a case study investigating intensive eye gaze intervention for accessing an augmentative and alternative communication device. The participant was an individual with cortical visual impairment and other comorbid disorders who had no formal means of communication. The intervention consisted of two phases, the first phase focused on eye gaze intervention programs/training and the second focused on the use of communication software. The participant developed sufficient eye gaze skills to access an eye gaze device for communication.

Acknowledgements

I would like to thank my advisor Dr. Jane Wegner for her guidance and support in the development and implementation of this thesis. It is through her mentorship that I have taken an interest in researching augmentative and alternative communication (AAC) and individuals with complex communication needs. She was also instrumental in her role as ACTS grant supervisor, through which I completed this project. The grant gave me the opportunity to research and the experience to be able to conduct a study involving AAC.

I would like to thank Allison Meder for her assistance with the administration of phase 1 of this study. I would like to thank Dr. Jonathan Brumberg, Jeremy Burnison and Kevin Pitt for their assistance in the development, administration and analysis of the EEG for this study. The EEG testing gave insight into Jacob's brain activity and has opened up possibilities for future projects.

I would like to thank Dr. Nancy Brady and Dr. Matthew Gillispe for their guidance and suggestions during the duration of this thesis. Their insight into the population with complex communication needs was very valuable in developing an appropriate intervention case study.

I also appreciate the support and guidance of my doctoral committee, Dr. Nancy Brady, Dr. Jane Wegner, and Dr. Jonathan Brumberg. They have given me great advice and suggestions for future projects that can develop from this thesis.

Finally, I want to thank my family and friends for their continuous support through my studies. I am very fortunate to have a strong support system of individuals who encourage me to continue my education and investigate the answers to my ever growing list of questions.

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Chapter 1

Introduction

This case study focuses on "Jacob," an individual with complex communication needs and multiple sensory deficits. Jacob originally came to the Schiefelbush Speech-Language Hearing Clinic at The University of Kansas to complete an augmentative and alternative communication (AAC) evaluation. The results of the evaluation were incomplete as his physical and sensory deficits made it difficult for him to access AAC devices through any method. The access methods attempted were eye gaze and auditory scanning with a toggle switch. The client was able to make a few selections, but the access methods were inefficient and the responses were not reliable. The most efficient method was determined to be eye gaze as Jacob's physical disabilities inhibited him from coordinating the hitting of a switch in response to auditory scanning. However, in the assessment sessions Jacob was not able to use the eye gaze access method reliably, though his potential was noted. Jacob needed intensive eye gaze training to determine if he could effectively access an AAC device through eye gaze. This study documents that training and his progress toward communication.

It is difficult to assess the true abilities and knowledge of a person if he/she has no means of communication. Many times these individuals cannot access AAC devices through traditional methods due to sensory deficits (e.g. organic hearing loss, cortical visual impairment, blindness) in addition to physical disabilities (e.g. dyskinesia, paresis) and/or cognitive disabilities (e.g. cerebral palsy, seizure disorder). Without access to communication it is difficult to assess the cognitive and language skills of these people as they have no reliable response method (Donegan et al., 2009). Access to communication allows us to better assess their abilities (Goossens', 1989). This study was an exploration in eye gaze training to access an AAC device. Eye gaze training programs were used to enhance Jacob's visual abilities and eye tracking skills. The end goal of this training was for Jacob to develop eye tracking skills sufficient to effectively access an AAC device through eye gaze

Cortical Visual Impairment

Jacob has a visual deficit of cortical visual impairment (CVI) which impacts his ability to use eye gaze software. CVI is a visual impairment resulting from bilateral dysfunction of the visual cortex and/or the optic radiations. The retinas themselves are not affected by this disorder; however, CVI can co-occur with other visual impairments including ocular and ocular motor disorders. CVI affects 30-40% of the population that is visually impaired (Roman et al., 2010). It is also the leading cause of visual impairment in children in developed countries (Matusba & Jan, 2006; Huo, Burden, Hoyt, & Good, 1999). There has been an increase in the population with CVI due to advancements in medical care leading to better survival rates for children affected by CVI and increased diagnostic abilities in detecting CVI. Individuals with CVI comprises a significant population and treatments are needed to enhance the visual abilities of individuals with this disorder.

As CVI is caused by either perinatal brain damage or trauma, the population with CVI often have other co-occurring disabilities. The most common cause of CVI in children is perinatal hypoxic-ischemic injury. Other common causes are infection, structural anomalies in the central nervous system, chromosomal and metabolic abnormalities, trauma and epilepsy (Matusba & Jan, 2006; Baker-Nobels & Rutherford, 1995). These etiologies also commonly cause other neurological deficits. In a study by Huo et al. (1999) patients' records were reviewed from a large pediatric ophthalmology referral practice. Data was gathered about the patients with CVI seen at this practice between the years of 1979-1994. Out of the 170 cases of CVI, 76.5% of the patients had associated neurological deficits. These neurological deficits included seizures (52.9%), and cerebral palsy (58.2%). Sixty-five percent of patients with CVI had ophthalmological deficits which caused additional visual problems. These included estropia, exotropia, ocular motor apraxia, nystagmus, optic nerve atrophy, refractive errors and retinal disease. As demonstrated by this study, a majority of individual with CVI have multiple disabilities and complex needs (Huo et al., 1999).

The visual deficits in individuals with CVI differ greatly from individuals with refractive deficits. Although CVI presents differently across individuals, there are common visual characteristics seen in this disorder. Individuals with CVI will have a normal eye examination, but their visual behavior is poor. CVI can cause apraxic eye movements and gaze palsies in which the eyes cannot move in the same direction. Visual field deficits may be present, which affects the individual's ability to detect objects in certain areas of their visual field. These individuals often have short visual attention spans and perform better in familiar settings. Light sensitivity is also seen in individuals with CVI, with some individuals gazing at lights and others exhibiting a fear of light. Some visual functions that are preserved include the perception of color and movement. Individuals with CVI often utilize their peripheral vision when looking for objects. They are also observed to bring objects close to their face to examine them in order to reduce a crowding effect. The crowding effect is created when objects or pictures are placed closely together. Individuals with CVI can better process information when each object or picture is viewed separately, as there is less visual information to process (Good, Jan, Burden, Skoczenski, & Candy, 2001; Groenveld, Jand, & Leader, 1990).

Treatment of CVI also differs from the treatment of other visual impairments. With ocular impairments the goal is typically to maximize the visual input by enhancing the visual environment. However, this technique has shown to be detrimental for individuals with CVI as they better process simplistic visual information. The goal in treatment of CVI is to maximize the individual's use of his/her functional residual vision. This requires several aspects including simplifying the child's visual environment, reinforcing visual information with tactile and verbal information and using rituals to maintain consistency in the child's environment. The child's strengths of the perception of color and motion are utilized by presenting objects with high contrast colors and putting the objects into motion (Good et al., 2001).

The visual abilities of an individual with CVI can be greatly influenced by the environment. Simplifying the environment and enhancing certain features of the visual stimuli is beneficial for individuals with CVI. It is important to simplify the visual input that the individual receives as to not overload the visual system (Groenveld et al., 1990). In a case study by Baker-Nobles & Rutherford (1995) a child showed increases in her response to visual stimulus when her environment was free from visual distractors and when high-contrast colors and lights were used. With these environmental adaptations and intervention, this child was able to learn to use a computer (Baker-Nobles & Rutherford, 1995). In addition to simplifying the individual's visual environment, it is important to maintain routines. Using similar routines everyday helps the individual predict what is coming next.

Children with CVI can experience improvements in their visual skills as Matsuba and Jan (2006) demonstrated in their long-term outcomes study for children with CVI. They found that children frequently improved their visual levels when compared to initial testing. In the population studied, 46% of children presented with higher visual levels when compared to initial testing. The children were more likely to improve when initial testing was done prior to age 3 and when the visual levels were higher at initial testing. Improved visual levels were also correlated with higher cognitive outcomes (Matsuba & Jan, 2006). Hoyt (2003) completed a similar study by reviewing clinic records and looking at improvements in visual levels for children with CVI. He found that in children who experienced striate cortex injury, 78% of children improved at least one visual level. In children who had periventricular white matter injury, 48% improved at least one visual level. The average time between testing was 5.9 years. Therefore, improvement in visual levels for children with CVI is commonly seen; however, it does depend on the area of injury (Hoyt, 2003). Huo et al. (1999) also found significant rates of improvement in visual levels after completing record reviews. In a population of 96 children with CVI and an average age of 3 years old at initial testing, 60.4% showed at least one level of improvement in visual levels upon later testing. Again Huo et al. (1999) found that children diagnosed before age 3 showed greater improvements. Improvements in visual levels and therefore, increased visual skills could be attributed to several factors. One possible reason for improvement argued by Sokol is that the visual system matures and residual potentials appear (as cited in Hoyt, 2003). Improvements may also be seen because the damage is not complete and, therefore, residual skills appear over time (Whiting et al., 1985). The most common theory of improvement in visual abilities of children with CVI is that the plasticity of the infantile brain plays a large role. Multiple studies demonstrate the increased rates of improvement in visual levels when the child is initially diagnosed before age 3, than after age 3. This data supports the theory that the plasticity in the young brain plays a role in increasing visual abilities in children with CVI (Huo et al., 1999; Lambert, Hoyt, Jan, Barkovich, & Flodmark 1987).

Most of the studies to date determined visual improvement based on improvement in visual acuity. With individuals with CVI there are also many visual behaviors that affect their visual abilities. Mamer (1999) found that visual stimulation could improve the visual acuity of children with visual impairment and additional disabilities, but did not improve visual behaviors. In this study ten students with visual deficits and additional disabilities were exposed to black and white drawings of varying contrast and density, 15-20 minutes a day four days a week for eight weeks. After the visual stimulation the students performed better on the Teller Acuity Cards indicating improved visual acuity. However, the visual stimulation did not change the targeted visual behaviors of eye blink, visual fixation, shift of gaze, turning away and reaching for an object (Mamer, 1999). These visual behaviors are important for functional use of vision and warrant further investigation.

Communication and Visual Impairment

There is limited research on the communication methods of children with CVI. Communication of children with visual impairment has been studied to some extent with a focus on young children. Most of the research looks at the verbal and non-verbal communication of these individuals. There is a lack of research on alternative and augmentative communication for individuals with visual impairment.

Some research has been done on the communication of individuals with congenital visual impairments. In a study by Tadic, Pring, & Dale (2010) it was found that children with congenital visual impairment and normal intelligence scored higher on standardized tests of language skills than their seeing peers. However, they showed decreased socio-communicative skills when compared to their peers. These socio-communicative skills were judged by the parents and many of the children had scores similar to individuals on the autism spectrum. These children had no other impairments that would inhibit them from learning language or speaking (Tadic et al., 2010). This deficit in pragmatics is seen from a young age in parent-child interaction as reported by Herrera (2015) in children with profound visual impairment between

18 and 24 months of age. It was found that of the children with visual impairments, those with poorer language abilities tended to respond non-verbally through a variety of ways (e.g. becoming quiet, leaning in one direction). However, the caregiver did not always recognize these non-verbal responses. Therefore, the children with higher language abilities had better overall interactions with the caregiver (Herrera, 2015).

The importance of non-verbal communication in children with visual impairments was also documented by Mallineni, Nutheti, Thangadurai, & Thangadurai (2006). This study investigated the non-verbal communication behaviors children with visual impairment produce and whether professionals of different fields observed these behaviors the same. The children in the study were between 2-8 years old and had a range of both visual impairment and developmental delay. A variety of non-verbal behaviors were observed for these children and the professionals did vary on their interpretation. The authors emphasized that all non-verbal behaviors need to be interpreted as purposeful communication, even if the child is not purposefully communicating. This helps the child control their environment and assign meaning to their actions (Mallineni et al., 2006).

One program that is focused on developing communication in children with visual impairments with or without co-occuring disabilities is the Radboud Sensis program (Vervloed, Hartog, Jespers, & Wals, 2005). It is designed for children under the age of 5 and trains the caregivers on how to best encourage their children's growth in communication. Vervloed et. al. (2005) trialed this program with four families to receive feedback on parent satisfaction. The parents were satisfied with the program, but did have suggestions for changes. The program focuses on improving the child's language skills and knowledge as well as improving the child's overall communication and interactions. The program trains the parents on the following topics:

basic communication skills, recognizing (pre)intentional behavior, adapting to the child's developmental level and interest, communicating about emotions and affect, choosing communication subjects, using adequate referential language and asking good questions (Vervloed et al., 2005). These are all skills that were determined to be at risk in parent-child interactions in children with visual impairment. This program does not address alternative methods of communication for children with visual impairment (Vervloed et al., 2005).

The Picture Exchange Communication System (PECS) using tangible symbols has been shown to be a possible means of communication for children with visual impairment and additional disabilities. Ivy, Hatton, & Hooper (2014) tested the use of PECS with tangible symbols with 4 children with severe visual impairments and multiple disabilities. All of these participants had less than 5 words or signs and were not using any tangible symbols for communication expressively at the beginning of the study. The participants were able to follow one-step directions and all attended a specialized school for students with visual impairments. Each child completed testing for preferential activities prior to intervention. At least 5 tangible objects were chosen to represent preferred objects or activities. These tangible symbols allow the child to receive input from a tactile source. The program trained the children to request the preferred activity by picking up and giving the tactile symbol to the communication partner. The intervention was intensive and one-on-one with the communication partner. All 4 participants were able to request preferred items or activities using PECS by the end of phase 1 of the study. However, the participants had difficulty generalizing the skill to a new communication partner. In the second phase of the study, only two participants reached mastery. Phase 2 began 3-4 months after phase 1 and involved an increased distance between the participant and communication partner (Ivy et al., 2014).

There has been some research documenting both the verbal and non-verbal communication of individuals with visual impairment. It is clear that these children do have something to communicate no matter how advanced their impairment is. Currently the research is scarce on alternative communication for individuals with visual impairment and co-occurring disabilities that inhibit verbal communication.

Eye Gaze Access

Eye gaze access for AAC devices is important for individuals who have no reliable control of any part of their body. Traditionally, an individual would access an AAC device through touch or a switch. Both of these access methods require controlled movement of a part of the body. Those individuals who did not have motor control sufficient to activate a switch had no ability to access a high-tech device until eye gaze access became available. These individuals relied on an eye transfer (ETRAN) board, a clear plastic board with letters or symbols, which the user would use to point with his/her eyes at a certain message. This system required a communication partner to interpret the message in order for the user to communicate. Eye gaze control of AAC devices allows the individual to access high-tech devices and computer programs. The individual can also communicate independently and does not need to rely on others to interpret the message (Donegan et al., 2009).

Eye gaze tracking was first used in 1947 to study the gaze of pilots after World War II using film and electrodes placed around the eyes to detect eye movement. Through the advancement of technology a head mounted system that recorded eye movement was then developed in the 1950s. The system was obtrusive and required the user to remain still while in use. As computer technology progressed the systems became more accurate and were able to analyze the recorded data more effectively. Currently, the most popular eye tracking systems are video-based. These eye tracking systems are available as head-mounted or non-intrusive systems and use either an ambient or an infrared light source. The cameras in the system then record and/or analyze the light that reflects off the eye to tell where the eye is looking (Mohamed, da Silva, & Courboulay, 2007). The Tobii eye tracking system that is used for the Tobii communication devices is a non-intrusive system and uses an infrared light source (Tobii Dynavox, 2015).

Donegan et al. (2009) studied the effects of eye control computer access for patients with various severe motor disorders which prevented them from accessing high-tech AAC by other means. The patients were categorized into three different groups: people with Amyotrophic Lateral Sclerosis (ALS), people with locked-in syndrome and people with severe difficulties, which included both physical and learning difficulties. These patients were located in four different clinics across Europe. In the first group three patients with ALS were administered the Satisfaction with Life Scale (SWLS) before and one week after a trial with the eye control system ERICA. The patients scored higher on most areas of the SWLS after the trial week with the system than before they were given the system. The patients all considered the system to be efficient, effective and comfortable and all were able to express complex communication skills (Donegan et al., 2009).

The second group the study examined was four individuals with locked-in syndrome. Before the introduction of an eye gaze system, these patients were using a switch and scanning access method for communication. Each patient was given a different eye gaze system dependent on his/her needs. After a trial with the eye gaze device the patients increased their rate and accuracy of communication when compared to the previous switch and scanning method they had been using (Donegan et al. 2009).

Finally, Donegan et al. (2009) studied individuals with complex physical/visual and/or learning difficulties. No formal data was analyzed for this group, but suggestions were given for working on eye gaze with this population. Each individual's trial was different and required different adaptations. Some of the difficulties that these users faced when using eye gaze access were a deficit in literacy skills, learning disabilities, visual deficits and head movements that were uncontrollable. There were steps that Donegan and colleagues found helpful when conducting the trials of eye gaze devices and increased the user's probability of success. First, it was important to gain understanding of the user's background including his/her abilities and difficulties. The environment should be controlled as much as possible so that the individual is comfortable and appropriate seating/positioning must be used so that the user can best access the screen (Donegan et al., 2009). These are all factors that were taken into consideration in this study and are important when trialing eye gaze devices.

Another common problem found across all three groups was difficulty with calibration. Calibration is beneficial when using an eye gaze system as it customizes the device to the user and the system can better track that individual's eyes. Some of the individuals did not understand the purpose of the calibration task and the researchers needed to make adaptations to the task in order to motivate the clients. These researchers found that it was best to start the trial with an introductory task that was fun and easy to give the individual a chance to try the system without feeling pressure. The team also worked together to adapt the device so that the user could experience success. This sometimes took multiple trials and collaboration with the manufacturing company (Donegan et al., 2009).

The individuals with complex physical/visual and/or learning difficulties experienced significant benefits when given appropriate devices and training in this study. Eye gaze control was life enhancing and had cognitive, physical and motivational benefits when compared to other AAC access methods for this population. Eye gaze was a powerful tool for individuals with complex needs and allowed them greater independence (Donegan et al. 2009). Eye gaze control benefits multiple populations and can be used both for communication and general computer access. However, different individuals face different challenges when using eye gaze control based on their varying abilities and sensory needs.

Display Considerations for AAC

Different aspects of AAC visual displays can affect the speed of selection of an icon in children with and without disabilities. Although no research has been conducted on individuals with CVI, research has been completed on display variables with individuals with normal visual processing. The effects of color on speed and accuracy of selection of icons on an AAC device has been studied in a variety of ways. Wilkinson, Carlin, & Jagaroo (2006) investigated the effect of differing colors of icons on an AAC display with typically developing preschoolers. These children had statistically significant greater accuracy and faster reaction time when each icon was a unique color compared to when the icons were all one color. This shows that having a unique color and shape for each icon, on an AAC visual display, can improve a child's accuracy and rate of response (Wilkinson et al., 2006). Thistle & Wilkinson (2009) also investigated the effects of foreground and background color on rate and accuracy of icon selection with young typically developing children. They found a statistically significant increase in rate of response when the foreground was colored compared to when the foreground was white. This shows the importance of making the icon itself colorful as its color yields a faster selection than a change in the background color (Thistel & Wilkinson, 2009). Finally, the effect of color on a visual display was studied with a group of both typically developing young children and children with Down

Syndrome. Wilkinson, Carlin, & Thistle (2008) investigated the effects of clustering icon colors on speed of selection with these groups of children. All children selected the designated icon significantly faster when the same colored icons were clustered together rather than separated (Wilkinson et al., 2008).

These studies show that color can have an effect on both the speed and accuracy of selection of AAC icons. Individuals with CVI have a strength of color perception therefore, color is an important consideration when modifying or creating communication boards. The results found with children with typical visual processing provides insight into beneficial adaptations for individuals with CVI. In the populations studied the children benefited when the icons were distinct colors (Wilkinson et al., 2006). Choosing distinct colors for icons is a potential way to improve accuracy and speed of selection for individuals with CVI. If it is necessary to have icons that are the same color it is best to cluster the icons by color to increase speed of selection (Wilkinson et al., 2008). Finally, the icon itself should be colored and not white as it was found that the colored foreground yielded a faster selection time (Thistel & Wilkinson, 2009). Further research is needed on the effects of color on AAC visual displays with the population with CVI as their strength in color perception and preference for contrast may yield interesting results.

Individuals with CVI also have a strength of detecting motion. AAC devices now have the options of dynamic icons that move. Little research has been done on the effects of moving icons when learning to use AAC. Based on the visual processing literature incorporating motion into the icons should increase attention to the icons and provide both novelty and contrast. However, it is still unclear how many icons should be animated or how the animation as a cue should be faded out. Animated icons could be beneficial to AAC users with CVI as they can detect motion well. Animated icons is therefore a potentially helpful cue for users with CVI, but it is still unclear on the amount of animation that should be used to cue the user to the icons (Jagaroo & Willkinson, 2008).

Eye Gaze and CVI

Multiple aspects of CVI make eye gaze access difficult for individuals with CVI. The presence of apraxic eye movements or gaze palsies in CVI make it difficult for the eye gaze software to track the movement of the eye, as it does not perform as a typical eye. The two eyes may be looking in different directions, which makes it difficult for the device to determine where the individual is looking. However, if the client has one reliable eye the device can be programed to track only one eye (Tobii Dynavox, 2015). The device works optimally when it is parallel to the user's eyes and about 23.5 inches away from the user's eyes. If the user is not in this position it can affect the precision of the eye gaze software (Tobii Dyanvox. 2015). Visual field deficits affect the individual's ability to view the entire screen of the AAC device. Depending on the individual's specific visual field deficits he/she may need the device to be placed off center so that the entire screen is free from the visual field deficit. However, the device would then not be in proper alignment which would negatively impact the precision of the eye gaze system. The optimum positioning of 23.5 inches away from the user is also difficult when trying to reduce the crowding effect that individuals with CVI experience. These individuals function better when objects or pictures are close to their face, but the device needs to be a significant distance away to function. However, the items on the screen can be simplified and reduced in number to reduce the crowding effect. Decreased visual attention span, also impacts the use of eye gaze software as the user needs to maintain their gaze on a particular icon for a set amount of time in order to select that icon. The system may be set so that items are selected by blinking, if the individual has the control to select in this manner. This selection method requires the user to look at an icon and then blink to select which could reduce the amount of gaze time necessary to select. The sensitivity to light does not significantly impact the use of eye gaze as the light in the room can be adjusted as well as the brightness of the screen. In this study the client's attraction to light was advantageous as the environment was manipulated to make the screen of the device one of the sole light sources in the room, attracting his attention to the screen (Tobii Dynavox, 2015).

Eye gaze access for AAC devices is a new technology that has the potential for unlocking the ability to communicate for many individuals who are without a means to communicate. Some individuals, like the participant in this study, need extra training and support to learn to use eye gaze because of sensory deficits. This case study was an exploration in eye gaze training software to increase an individual's visual abilities necessary for eye tracking software. The goal of the study was that he would have sufficient visual skills, at the end of training, to begin communication intervention using the Tobii I-12 communication software through eye gaze access.

Chapter 2
Methods

The Participant

At the beginning of the study Jacob was 14-year-old male with no reliable means of communication. He had been diagnosed with a chromosome 13 q subtelometric deletion, encephalopathy (static) with microcephaly, cerebral palsy, quadriplegic, developmental delays, seizure disorder, cortical visual impairment, esotropia and astigmatism. Jacob presented with uncontrollable movements and minimal voluntary control of his limbs. He was not able to produce any spoken words or produce a reliable yes/no response. Jacob communicated through facial expressions, laughing, crying and vocalizations. He demonstrated his likes and dislikes through facial expressions and body language. For example, when a video was shown that he did not like he would have a neutral facial expression and turn his head away from the researcher. However, when it was a video he enjoyed he smiled at the researcher and waved his arms in excitement. It was not clear what Jacob's cognitive abilities were, as his physical and sensory deficits inhibited accurate assessment.

Jacob had multiple disorders impacting his vision including Cortical Visual Impairment (CVI), alternating estropia and astigmatism. Cortical Visual Impairment is caused by a dysfunction in the visual cortex or optic radiations and the resulting vision varies from person to person (Roman et al., 2010). Estropia is a turning-in of the eye(s) so that they are not aligned (Cooper, Cooper, & Press, n.d.). Three surgeries had been performed to correct for Jacob's estropia and it had improved. He also presented with astigmatism that affected the clarity of his sight. He wore glasses to correct the astigmatism. Jacob's visual skills were regularly monitored and measured as his vision could change. A functional vision evaluation and learning media assessment was completed at another facility in 2014 when Jacob was 13-years-old. Multiple factors of Jacob's vision were assessed by the team. It was determined that his near sight visual acuity was best within 6-12 inches from his face and he could perceive people at the distance up to 2-3 feet away. He presented with visual field deficits in the upper, lower and right visual fields. This was seen when tracking a light source; he was able to track it in the left field, but would lose the light in the upper, lower and right fields. He was observed to fixate with one eye at a time on brightly colored pictures, 4 inches or larger when presented within 12 inches from him and given auditory cues. Jacob did reach for desired objects by first looking at the object and then looking away when he reached; however, this method affected his accuracy. Environmental factors could positively impact Jacob's visual abilities, including decreased background sounds and familiarity with the environment. Jacob could also better see objects in motion and used auditory cues to enhance his vision. His visual attention could be brought to objects outside his visual field if auditory cues were given.

Jacob's auditory skills were difficult to assess due to his inability to respond through traditional methods and his co-occurring disorders. Jacob had passed auditory brainstem response testing along with tympanometry. However, the Functional Auditory Performance Indicators (FAPI) was administered in 2010 and concerns with Jacob's auditory skills were noted. This measure indicated that Jacob's auditory development was delayed and that he did not have typical auditory development or processing of speech or oral communication. It was suggested that he could have a central auditory processing disorder. However, his auditory skills were difficult to assess as he was not able to vocalize his responses or have controlled, fluid movements. Auditory skills that Jacob did exhibit were responding by turning his head when spoken too and laughing in appropriate situations. It was recommended that Jacob receive input from all sensory sources, visual, auditory, and tactile, to process information as his true skills cannot yet be assessed.

Past intervention. Jacob received multiple services through his school including music therapy, speech and language intervention, physical therapy, occupational therapy, adapted physical education, indirect vision services, and special education services. He spent approximately half of his day in the general education classroom for the subjects of language arts, social studies, electives and lunch, and half of his day in the special education setting. In school, intervention was primarily focused on increasing Jacob's ability to communicate through visual fixation, touching an object, imitating movements and increasing his knowledge of cause and effect relationships.

One goal on Jacob's IEP that demonstrates the type of task used to increase visual fixation was, "while hearing a song or story within a refrain or a rhyme play activity and given a pause of up to 30 seconds, Jacob will indicate engagement with the story by visually fixating on the book or IPad in 4 of 5 opportunities" (IEP, 2014). The team also worked on combining visual fixation with touch through the goal of "upon presentation of an object in his visual field, Jacob will visually locate the object and touch it within 15 seconds in 3 of 5 opportunities" (IEP, 2014). Beyond these goals, no specific eye gaze training programs were being used. The technology that was used with Jacob was an iPad for the previously mentioned goal and for teaching cause and effect, "when presented with a familiar cause-and-effect activity on the iPad, [Jacob] will touch the screen to activate the visual and accompanying sound by touching the iPad screen within 30 seconds on 1 of 5 opportunities" (IEP, 2014).

Jacob's mother reported that switches had been used with him in the past for communication purposes, but had not been implemented regularly. Sign language and a visual schedule were used with Jacob throughout his day to give visual input in addition to the auditory input. Learning sign language or the use of a visual schedule were not Jacob's goals at the time of this study, but were adaptations that were used throughout the school day. Jacob received indirect vision services which included the adaptations of simplifying visual input, enforcing routines and pairing visual information with auditory cues. Jacob's primary means of communication at school were facial expressions, visual fixations, and body movement.

The Intervention

Jacob participated in the study at the Schiefelbusch Speech-Language-Hearing Clinic at the University of Kansas for 58 half-hour intervention sessions. The purpose of the intervention was to develop Jacob's eye gaze skills so that he could use the Tobii I-12 device to communicate. With that goal in mind, the intervention was divided into two phases. The first phase included 31 sessions focused solely on eye gaze training. During this phase Jacob completed activities on eye gaze training programs, which are designed to develop eye gaze skills. The second phase was 26 sessions in length and focused on introducing the communication software. The sessions during this phase were primarily spent using the Tobii Communicator 4 software. The progression of the sessions was tailored to Jacob's needs and rate of learning.

The environment. When setting up the intervention room for this study the researcher took into account the environmental factors that can affect CVI. Personal factors specific to the client were also taken into consideration. A simple therapy room was used with no outside windows to control for the lighting in the room. Visual distractors, such as tables or posters, were moved out of the client's direct line of sight. The overhead lights were turned off and a lamp was turned on behind the client to provide low level lighting without a distracting light source.

Consistency of the environment was maintained by providing therapy in the same room, unless circumstances would not allow for this. When a different room was used for three sessions, Jacob was very distracted from the task and was looking around the room for the majority of the time.

The equipment. One of the pieces of Jacob's background history that was important to consider when using eye gaze was his diagnosis of CVI. Many of the common characteristics of CVI effect eye-gaze access of AAC devices. The device used in this study was the Tobii I-12 device. This system uses an infrared sensor to detect where the user's eyes are looking on the screen. After the user maintains his/her gaze on an individual icon for a set time that icon is selected. Aspects of CVI will be discussed in relation to the Tobii I-Series systems.

Positioning. The client was situated in the middle of the room and was seated in his wheelchair. His wheelchair was tilted slightly backward (mark 10 on the wheelchair) so that he was upright and comfortable. In the initial sessions, Jacob's caregiver needed to assist with his positioning at times. When Jacob started to slump to the side he would need to be repositioned so he was straight in his chair. Positioning was key when using the eye gaze device. If Jacob was off center his eyes were not in the middle of the screen and the device could not read his eyes well. When it was difficult for Jacob to maintain good positioning, a chest support was attached to his wheelchair to stabilize him. The headrest of his wheelchair also helped to stabilize Jacob's head. The researcher sat at the side of Jacob for the majority of the session. During the majority of the first phase the researcher sat on Jacob's left side. The researcher then switched and sat on Jacob's right side during phase 2 to help attract his attention to his right visual field. If he was visually fixating to another area of the room other than the screen, the researcher would stand behind the device to direct Jacob's attention back to the screen.

The Tobii I-12 was placed on a hospital rolling mount. This was a helpful mount as it could be easily adjusted around Jacob's wheelchair. The device was placed slightly left of Jacob's midline. This was done as Jacob showed preference for his left eye and the left field was his best visual field. The distance between the device and the client's eyes was 19 inches. This distance was determined to be best by using the track status viewer box. This box shows the client's eyes in a black box and a distance gradient on the side of the box with an arrow that indicates whether the user is too close or too far from the device. At 19 inches Jacob was in the green area of the track status viewer which indicates he is at a good distance for using the device.

The device would not calibrate to the client as there was insufficient data for calibration. This was due to his visual deficits and uncontrollable movements. Therefore, the researcher calibrated the device to herself, in a seated position similar to the client, before the sessions began. At the beginning of each session the researcher also started the gaze viewer software which recorded Jacob's gazes. This software recorded a heat map of where Jacob looked and recorded the pattern of his gaze. The device was set to a 300 millisecond dwell time, which was determined to be suitable for Jacob after several trials.

The eye training programs. The Look to Learn and Sensory Eye-FX programs were used. The Look to Learn program has 40 activities and is designed for beginning users of eye gaze. The purpose of the activities is to increase an individual's access to the device and improve the user's skills in choice making. The activities are separated into five different skill areas: sensory, explore, target, choose, and control. The sensory activities focus on teaching cause and effect. Explore concentrates on getting the user to use the whole screen. The target activities work on the user's eye gaze accuracy. Then the program focuses on choice making skills in the choose level. In the final level, control, the program corrects small errors and develops the drag and drop skills (Sensory Software International, n.d.).

The Sensory Eye-FX program has 5 levels containing a total of 30 applications. The first level is blank screen engagement which is meant to engage the user with cause and effect applications. When the user looks at the black screen an action occurs on the screen and stops when he/she looks away. The program then moves to object displacement in level two. These activities again are on a primarily black screen, but require more skills from the user including dwell and simple targeting. The next level is zoned focusing which works on encouraging the user to scan the screen and fix his/her gaze in certain areas of the screen. Level four is active exploration which includes fun activities that encourage the user to explore the whole screen. Finally, the program moves to controlled targeting in level five, which increases the user's control of eye gaze including improving accuracy and dwell (Sensory Guru, n.d.).

Recording eye tracking data. The Tobii Gaze Viewer program allows the researcher to record eye tracking data from a user of Tobii technology. The information can be saved as images or movies. In this study the gaze data was saved as images for evaluation. The software shows a heat map and gaze plot of all the areas the user has viewed on the screen. The heat map and gaze plot are superimposed over the image that the client was viewing at the time. The heat map gives clear evidence of what areas of the screen the user was looking at the most and what areas the client did not look at. The gaze plot shows the order of the user's gaze allowing the researcher to determine what the user looked at first and what was viewed last (Tobii, n.d.).

Communication software. Jacob used Tobii Communicator 4 in the second phase of this study. Tobii Communicator 4 is a communication program designed for individuals who need assistive technology to communicate. This program provides multiple different page sets that can be customized for the user, as well as multimedia communication through use of the internet (Tobii, n.d.). During the first four sessions of phase 2, when the communication software was being introduced, a specialized board with a 6 icon display was used. This display had relevant vocabulary (e.g. stop, more, start) for activities that interested the client (e.g. listening to music, watching a video). After Jacob demonstrated his ability to use this type of board, he progressed to a ready-made page set called Sono-flex as it provided access to an expansive vocabulary set. The Sono-flex vocabulary set uses color coding to indicate word type (e.g. verbs are green, nouns are yellow). This helps to teach vocabulary and sentence structure to the user. There are also clearly marked pages of core words that can be used in many contexts. Sono-flex also offers context pages that can be changed depending on the activities the user is completing. The context pages used the most with Jacob were the reading and television context pages. The researcher used these pages of vocabulary during activities with Jacob. These pages gave Jacob access to vocabulary that related to the activity. The buttons on the Sono-flex vocabulary were one inch by one inch in size and had colorful icons on a white background (Tobii, n.d.) This program also allows for hiding of icons. This was used on certain pages to hide vocabulary that was not relevant for the activities. This helped to reduce the crowding effect that Jacob may experience due to his CVI. He was also introduced to new vocabulary slowly to allow him to process the information.

The Training

Phase 1. Each session was administered by either the researcher or a doctoral student who was a speech-language pathologist that was trained in the intervention protocol and had experience with AAC. In the first phase of the study, the focus was solely on teaching Jacob the visual skills needed to operate the device. This was done through the use of two eye gaze training programs, Look to Learn and Sensory Eye-FX. No communication software was used during this phase as Jacob did not have the skills to operate the software. The 30-minute sessions were equally divided between the two training programs during the first phase. Look to Learn was administered first for 15 minutes, followed by Sensory Eye-FX for 15 minutes. On days that the participant arrived asleep or restless, the session began with watching a preferred short video clip until Jacob was awake and appeared ready to work. The session was then administered as usual and no time was subtracted from the other activities.

Progression through program levels. Each of the eye gaze training programs consisted of 5 levels of activities. The researcher wanted to ensure that Jacob had mastered one level before moving to the next so that he could build his eye gaze skills successfully, without frustration. The Look to Learn software contained a workbook of sheets to track a user's progress in the program. Each activity has a worksheet with specific skills on which to rate the user, an example sheet is shown in Figure 2.1. The first five skills are specific to the activity and the clinician must judge whether the skill is not demonstrated, developing or achieved during the activity. The last four areas to rank the user on are the same for every activity. This section asks the clinician to rank the user on a scale from 1 (low) to 5 (high) on the levels of: facilitation, motivation, enjoyment and overall success. There is also an area to record a P scale. The ICT P scale is a ranking system used in the United Kingdom to record a student's performance when below the Level 1 of their National Curriculum (Sensory Software International, n.d.). The workbook provides an explanation of each P scale level and provides examples of what skills should be demonstrated at each level. The researcher created a similar recording sheet for the Sensory Eye-FX activities as shown in Figure 2.2.

Figure 2.1. Look to Learn Data Collection Worksheet

appeared more tired today 7

Custard Pies
Look at each photo as it appears on the screen to throw a custard pie. This activity is great for analysing responses to content appearing in different areas of the screen.

TIPS
- *Use photographs of family and friends to motivate the user*
- *Good for analysing targeting skills*
- *Observe and help if the user is getting close to the target*

Learning objectives:

Date: 6/15 **Time of day:** **Time spent:** 12 min

	Not Demonstrated or N/A	Developing	Achieved	Observations and Targets P3(ii)
Establishes screen engagement			√	
Targets static images			√	
Able to access all areas of the screen			√	top of screen is difficult Couldn't get top left first time but got it the second time
Responds appropriately to facilitator's instructions			√	
Able to hit all targets			√	

LEVEL	1 Low	2	3	4	5 High	Comments
Level of facilitation				√		Pointed occasionally stood behind screen to direct attention
Level of motivation			√			verbal Prompts
Level of enjoyment				√		tired at start but perked up when he hit targets
Overall success				√		

Name of user:

Calibrated: Y X N

User's position:

Built-in analysis used: Y N

Comments:

Facilitator:

Personalised images / video used: Y N

Device position:

4

Figure 2.1. Completed Look to Learn data collection worksheet of a mastered activity from session 7.

Figure 2.2 Sensory EyeFX Data Collection Sheet

12

Activity: Dwell Bomb Level: Level 2 Date: 7/16 Time of day: Time spent:

Clinician: Calibrated? Y/N User's position: Device position: Left of midline

P6

	Not Demonstrated or N/A	Developing	Achieved	Observations and Targets	P score
Establishes screen engagement			√		
Targets static images			√		
Able to access all areas of the screen			√		
Responds appropriately to facilitator's instructions			√		
Able to hit all targets			√		
Dwells for bomb to go off			√		

Level	1 Low	2	3	4	5 High	Comments
Level of facilitation		√				
Level of motivation					√	
Level of enjoyment					√	
Overall success					√	

Didn't need much instruction.
Started as soon as it came up.

Figure 2.2 Completed Sensory EyeFX data collection sheet of a mastered activity from session 12.

It was determined that mastery of an activity would occur when Jacob received a score of "achieved" on all the skills indicated on the worksheet for that activity. He also needed to receive a score of 4 or above on the levels of motivation, enjoyment and overall success and a score of 3 or below on the level of facilitation. The goal was for Jacob to demonstrate eye gaze skills with limited assistance from the researcher. A P scale was also given for each activity, but not considered when determining criteria for mastery. In order to master a level, Jacob needed to master 5 of the activities in a level to progress to the next level of the program.

Intervention strategies. The researchers used a variety of teaching strategies throughout the therapy sessions. In the initial sessions, Jacob needed maximum support to use the device. However, as the study progressed support was faded to allow for Jacob's increased independence. Redirection was used frequently in the initial sessions as Jacob was learning to use the device. Jacob often looked at other objects in the room or at the researchers. In these instances, he was redirected through verbal and visual cues to look at the device. General and specific verbal cues were used to tell Jacob where to look (e.g. look at the screen, look at man with the silly face in the corner). It is thought that verbal cues can be helpful for individuals with CVI to put meaning to the visual input they are receiving. Individuals with CVI are not able to process visual information as their seeing peers do. Therefore, they need other forms of input to make sense of the incomplete visual input they are receiving (Groenveld et al., 1990). Visual cues were also used to attract Jacob's attention to the screen. Due to his diagnosis of CVI Jacob responded well to viewing movement. The researcher waved her fingers or an object in front of the screen to attract Jacob's attention to the device.

Modeling was also consistently used in the initial sessions and when a new level was introduced. The researcher used her finger to activate the device and show Jacob how to complete the activity. This was done at the beginning of the activity if Jacob did not engage with the activity right away. After given a model, Jacob usually began participating in the activity independently.

Phase 2. After Jacob acquired eye gaze skills sufficient enough to access the communication software the study progressed to phase 2. This occurred when Jacob reached level 3 on Look to Learn and level 4 on Sensory EyeFX. In the second phase of the study the focus was on teaching Jacob to use the Tobii Communicator 4 software to communicate. During the second phase, Jacob completed one activity on an eye gaze training program for five minutes as a warm-up activity and spent the remaining 25 minutes using the Tobii Communicator 4 software.

During the second phase of the intervention, when using the Tobii Communicator 4 software, several activities were completed. First, Jacob and the researcher had a conversation. This gave Jacob time to explore the device and the vocabulary sets. The researcher asked Jacob questions and led him to vocabulary pages where he could answer the questions. Jacob also initiated by using different vocabulary and the researcher interpreted the meaning depending on the context. Next the researcher chose either reading or video for the activity. The corresponding vocabulary context page was selected to give Jacob access to relevant vocabulary. For both the reading and video Jacob was given multiple options from which to choose. After he made a selection on the book or video he wanted, the researcher read or pressed play. In the middle of the book or video the researcher stopped and asked Jacob whether he wanted to keep going or choose another book or video. He then made that choice by selecting the appropriate vocabulary. Jacob's utterances were recorded by the researcher and then analyzed in the Systematic Analysis of Language Transcripts (SALT).

Intervention strategies. As the study moved into the second phase and the communication software was introduced; the researcher used aided input when communicating with Jacob. She asked questions, stated feelings, made comments and requested activities using the icons on the device while saying it out loud. The researcher provided wait time after asking a question or making a comment to allow Jacob time to respond. Jacob often needed 5-7 minutes wait time to respond. However, his responses were appropriate and he rarely made an incorrect selection. After Jacob made an utterance the researcher prompted him to expand his thought. She asked questions about what he said and prompted him to elaborate by giving suggestions. The researcher also used verbal cueing when teaching the communication software. She pointed to different vocabulary word options and labeled them so that Jacob knew what the different vocabulary words were and where to find them.

EEG. An electroencephalogram (EEG) was completed on Jacob as a part of this study to determine if Jacob could recognize known images paired with the verbal word. Pictures were taken of three objects that were familiar to Jacob and which he used in everyday life. These objects were paired with three images and words that were unfamiliar to Jacob. The words were recorded by the researcher that Jacob was familiar with so he would recognize the voice. These six items were presented in random order to Jacob on a computer screen using high contrast backgrounds for the images and with the sound presented from speakers. Jacob was fitted with an EEG cap and electrodes. He had worn the cap with electrodes in previous sessions to grow accustom to the feeling on his head. At the beginning of each trial the target word and picture were presented to Jacob and he was asked to pay attention to that target image/word pair. The six stimuli were then presented in random order to Jacob as the EEG was conducted.

Chapter 3

Results

Phase 1 Eye Gaze Training

At the end of this study Jacob reached level four on the Look to Learn eye gaze training program. He mastered four of the activities within level four; therefore, he needed to master only one more activity to move to level five. Jacob also reached level four on the Sensory EyeFX software. At the end of the study he had mastered three of the activities within level four. The progression through Sensory EyeFX was slightly modified. Jacob only mastered four activities on level two and three of the activities on level three of Sensory EyeFX before moving on to level four. Figure 3.1 shows the number of sessions it took for Jacob to master a level in each program.

Figure 3.1 Mastery of Levels in Eye Gaze Training Program

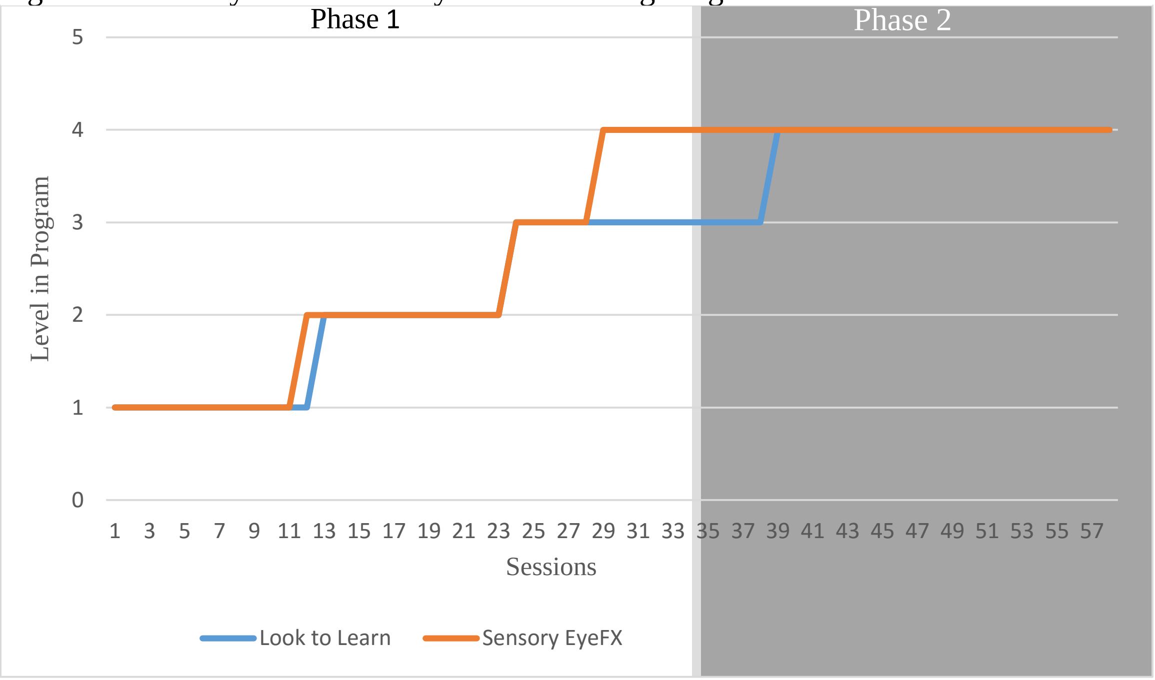

Figure 3.1 Shows number of sessions to master a level. Each time the line vertically ascends, a level was mastered. The grey section indicates the beginning of phase 2 when Jacob had a total of 5 minutes on eye gaze programs per session.

During phase 1 Jacob interacted with two different researchers. In order to ensure fidelity of the treatment sessions an independent rater was trained in the reliability protocol and rated 20% of the phase 1 sessions. The sessions judged were divided between the two researchers. The treatment reliability was judged on four different areas including: the device is situated left of the participant's midline, the overhead lights are turned off and a lamp is turned on behind the participant, Look to Learn program was administered for 15 minutes and Sensory EyeFX Software was administered for 15 minutes. The treatment sessions were 93% reliable across the two researchers. More in-depth reliability was attempted on the scoring of the activities. However, the poor quality of the recording inhibited the rater from scoring the activities.

Phase 2 Communication

The Tobii Communicator software was introduced after 31 sessions of eye gaze training. Eye gaze training continued to be a part of phase 2 by using the software during a 5 minute warm-up at the beginning of each session. Jacob's utterances were recorded each session. Figure 3.2 presents Jacob's number of utterances per session using the Tobii Communicator 4 software. He produced an average of 11.7 utterances per session. Jacob produced a total of 369 words during this study using both the specialized communication board and Sono-flex user. Out of those words he produced 155 different words. His number of different words was also calculated for just the communication that occurred using the Sono-flex user. In these sessions he produced a total of 345 words with 152 being different words.

Figure 3.2 Utterances per Session

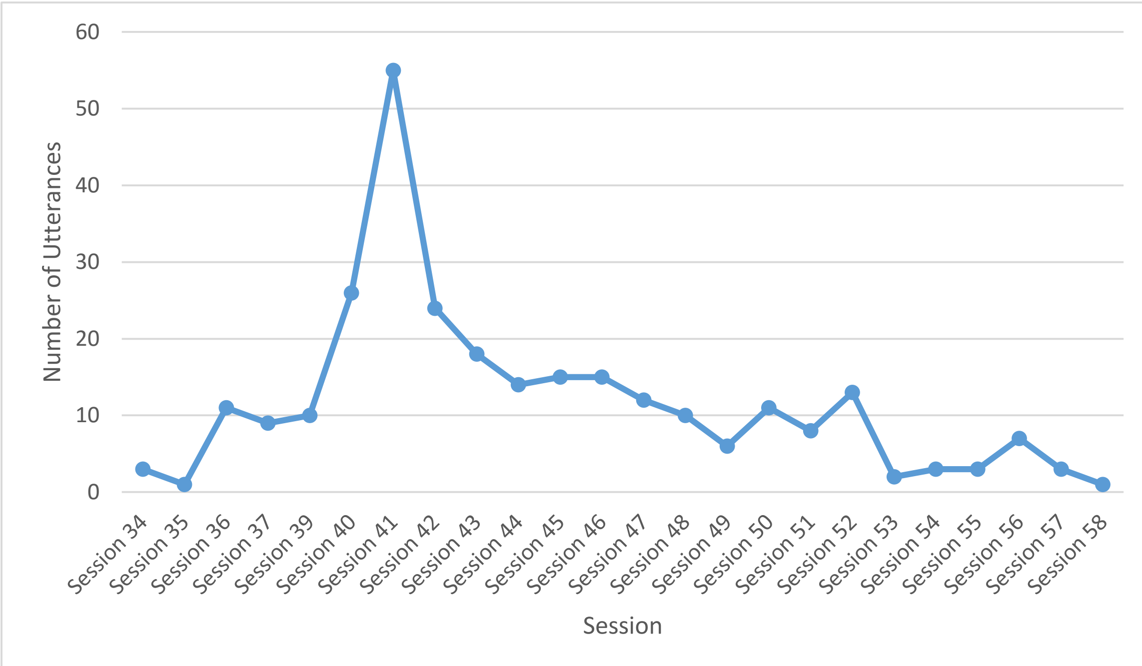

Figure 3.2. Number of utterances per session produced in phase 2.

Jacob produced many different types of utterances during the intervention. The majority of his utterances were comments or initiations. He produced 55 initiations and 51 comments. Initiations were any utterance that Jacob produced that was not in connection to something we were already discussing. Comments were related to the activity or discussion we were having and were often a statement of feeling or an observation of the environment. Jacob answered 45 questions provided by the researcher and made 45 choices. His choices were typically the type of video to watch or book to read. Jacob also asked 14 questions to the researcher. He made 4 requests or commands; these were made without a prompt from the researcher. Although most of Jacob's utterances were 1 word utterances, he also began combining icons to create longer sentences. He produced 11 two word combinations and 1 three word combination. See Appendix A for examples of utterances.

Heat Maps and Gaze Plots

Heat maps and gaze plots were taken during every session. The heat maps give a representation of the number of times the user looked at different areas of the screen by color coding based on concentration (e.g. green for a small number of gazes, red for a high number of gazes). Gaze plots coordinate with the heat maps and a circle with a number is placed at every place that the user looks. The numbers show the order in which the user looks at different areas of the screen.

Figure 3.3 depicts the number of gaze points recorded at each session. The gaze points were recorded from the gaze viewer software. Jacob averaged 166.8 gaze plots per session. See Appendix B for examples of some of the heat maps and gaze plots recorded at different points during the study.

Figure 3.3. Number of Gaze Points per Session

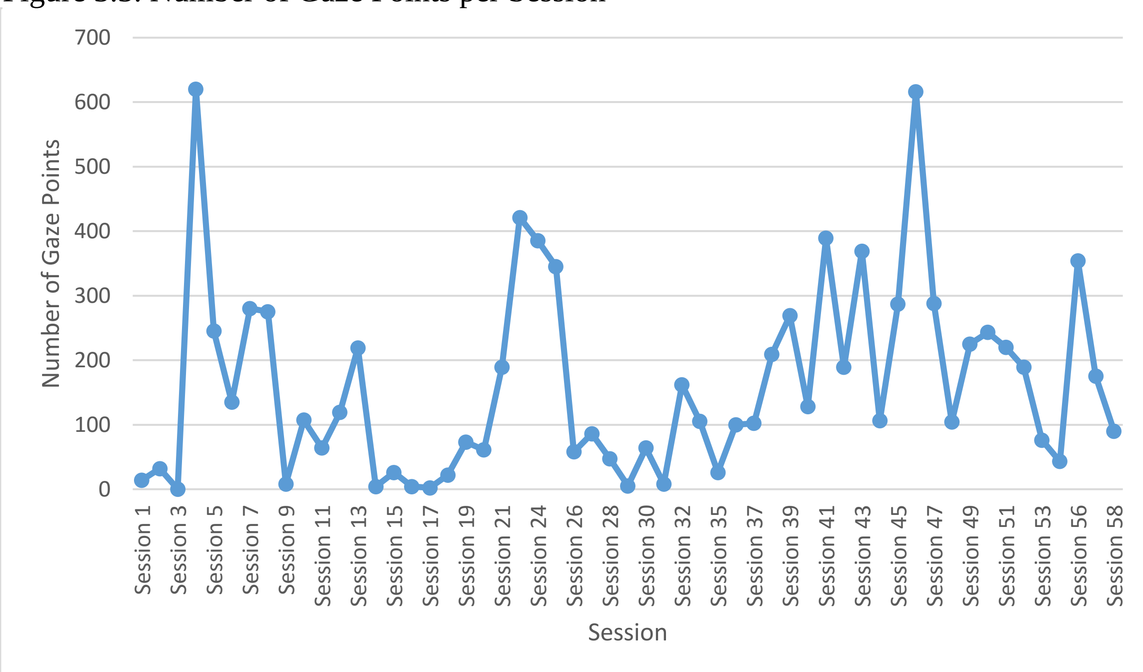

Figure 3.3 Number of gaze points per session for both phase 1 and phase 2.

Figure 3.4 is the resulting data from the EEG conducted on Jacob. The blue lines indicate the target stimuli and the red lines indicate the non-target stimuli. Each graph is data from a different electrode.

Figure 3.4. EEG Data

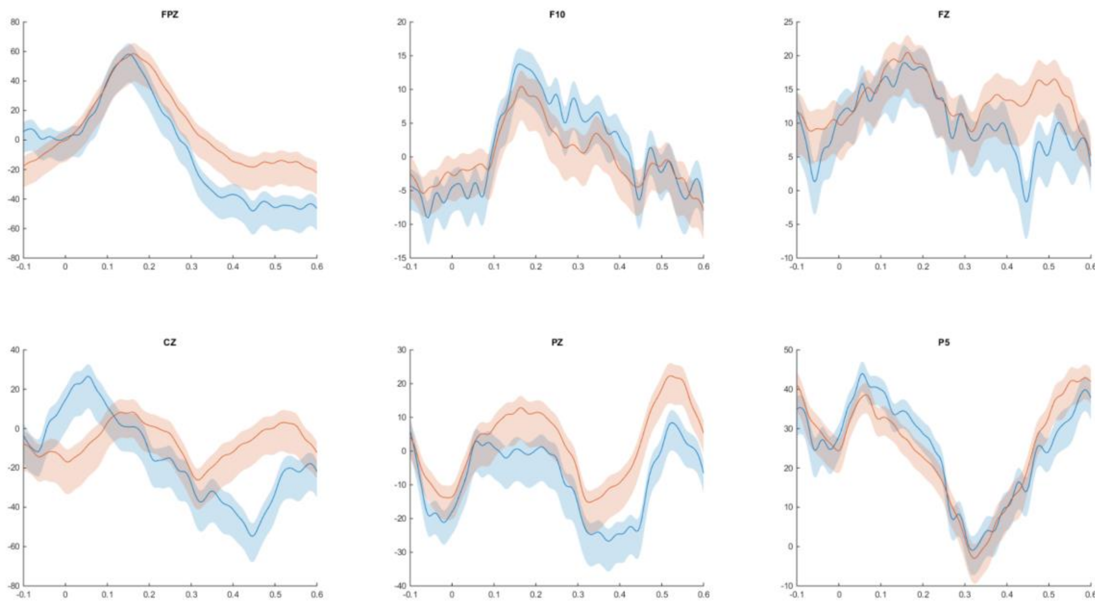

Figure 3.4. EEG data depicted for 6 electrodes. Gaps between lines indicate a significant difference.

Chapter 4

Discussion

This study consisted of two phases of intervention. Phase 1 focused on developing Jacob's eye gaze skills so that they were sufficient enough to access a device for communication. When Jacob demonstrated adequate eye gaze skills for accessing communication software, Phase 2 began with a focus on teaching Jacob to communicate. The study consisted of a total of 58 half-hour sessions spanning seven months. There was an average of 2-3 sessions a week and three occurrences in which there was a break between sessions lasting a week or more. The study was originally designed to be more intensive with 4 sessions a week for 16 weeks. However, due to illness, difficulties with transport, and appointment conflicts the study was adapted to the participant's availability and thus less intensive.

Phase 1 Eye Gaze Training

Jacob expanded his eye gaze skills in phase 1 of this study. His improvement was shown through increased number of gaze plots on the screen, a greater area of the screen covered by the heat maps and an increased ability to dwell to select. In 58 half-hour sessions, 24 of which were spent primarily on communication software, Jacob reached level four on both the Look to Learn and Sensory EyeFX softwares. At this level, the programs required Jacob to demonstrate choice making skills, dwell to select and engage with the whole area of the screen. By the end of the study Jacob had mastered four activities of Look to Learn level four and three activities of Sensory EyeFX level four. In order to master these activities and the previous levels, Jacob had demonstrated an ability to dwell to select, to access the majority of the screen and to track objects on the screen. During the course of this study, he was able to progress from minimally engaging with the screen, to tracking and dwelling on complex images. He was also able to maintain his attention to the screen for longer periods of time and increased his motivation.

Jacob's eye gaze skills developed over the course of the study. At the beginning of the study Jacob would look at the screen for a short time and his gaze was restricted to the bottom and left side of the screen. During this time the focus of intervention was on encouraging Jacob to engage with the screen. He quickly tired from the activities, which he expressed by looking off to the other side of the room or becoming restless in his wheelchair. After the first three sessions, a significant difference was noted. He was more alert and engaged in the activities. This change in motivation and engagement was also seen in the gaze plots. During the first three sessions Jacob averaged 15 gaze plots per session, by the fourth session he produced 620 gaze plots. His increased abilities within the first sessions was also shown through his mastery of 4 activities between sessions 5 and 7. The increase in gaze plots and mastery of activities within the first 7 sessions indicated that his eye gaze skills were increasing quickly with the eye gaze training programs.

After Jacob showed consistent engagement with the screen in level 1, other skills could be targeted. Next, the programs concentrated on encouraging Jacob to look at specific areas of the screen and to maintain his gaze for longer periods of time. Both of these skills were then joined to develop Jacob's ability to dwell to select. This required him to target an area of the screen and look for a specific amount of time. Finally, the other important skill that Jacob gained from the eye gaze training programs was the ability to track an object on the screen. In order track he needed to maintain his gaze on the screen as well as access the whole screen. By the end of this study Jacob's eye gaze skills had developed to the point where he could track objects on the screen and dwell for a sufficient time to select an item. These are the skills that he needed to access the communication software.

Jacob's number of gaze plots varied throughout the study while learning these different skills. One trend was noted in the gaze plots, 47% of sessions that presented with 65 or less gaze plots occurred on the first session of the week. There are several possibilities to explain why Jacob had decreased gaze plots at the beginning of the week. One possibility is fatigue from the weekend and beginning his school week again. Another possibility is that Jacob had several days off from intervention and experienced some regression of his eye gaze skills. However, other evidence contradicts this hypothesis as Jacob maintained his eye gaze skills over multiple days at other points in this study. For example, there was a two week break between sessions 45 and 46. In that time he increased his gaze points from 287 on session 45 to 616 on session 46. Therefore, Jacob occasionally showed regression of skills after a break in intervention and other times he maintained his skills. Another observation was made about the sessions with fewer gaze plots. Forty-one percent of these sessions occurred in the same two weeks. It cannot be determined why those two weeks were difficult for Jacob as he had high numbers of gaze plots before and after these two weeks. Another 17% of the sessions that presented with 65 gaze plots or less were comprised of the first 3 sessions of the study, which was expected to be lower as he was at the beginning of intervention.

In addition to an increase in gaze plots, Jacob also increased the area of the screen that he viewed throughout phase 1. In the initial sessions the heat maps revealed that his gaze was restricted to primarily the bottom and left side of the screen. As treatment progressed he was able to access the middle and right side of the screen. By the end of phase 1 he was able to access areas on the very top of the screen. Jacob progressed from a viewing a limited area of the device to accessing all areas of the screen. Examples of Jacob's expanding eye gaze skills as demonstrated by the gaze plots are found in Appendix B. This large improvement in Jacob's range of vision and subsequent increased success in the eye gaze programs was surprising given the CVI literature. The literature states that increasing the visual field increases the chance for interference of other visual information and therefore increases the crowding effect for individuals with CVI (Groenveld et al., 1990). This did not appear to be the case with Jacob, as his visual field increased he demonstrated greater success and developed more eye gaze skills.

It should be noted that there were two deviations from the original criteria in order for Jacob to reach level four on Sensory EyeFX. He mastered four activities on level two and three activities of level three before moving on to the next levels. The original criteria for mastery is achieving five mastered activities before moving to the next level. The alteration was made because he appeared uninterested in the last activities of levels two and three. He would turn his head away from the screen when they were attempted. The remaining activities were some of the least visually and auditory stimulating activities in the program. It was decided to move Jacob to the next level and if he did not experience success, he would be moved back to down to the previous level until it was mastered. Jacob did master activities on both of levels three and four, which indicates he possessed the skills necessary for those levels. Jacob likely did not master those activities because they were not motivating for him, not because he did not possess the skills. It is important to remember that individuals with complex needs perform better when they are motivated, just as their peers do. They also demonstrate refusal, but many times it manifests in a different way as they are not able to verbalize. It is important to be attentive to the client's behaviors when their progress declines to determine if the change is due to a lack of skill or a lack of motivation.

The alteration in criteria was made to keep Jacob motivated and to maintain his progression through the program. Motivation was a key component to Jacob's success on the eye gaze training programs. The activities that he found enjoyable, which he demonstrated through smiling and laughing, he mastered faster and with greater ease than the other non-motivating activities. Aspects of the activities that he expressed enjoyment in were interesting sounds, movement, and bright colors. These are all aspects that would be expected that Jacob would be motivated by due to the characteristics of CVI. As previously discussed, the goal of treatment for CVI is to maximize the use of the individual's functional residual vision. Traditionally, this was done by simplifying the visual environment, reinforcing visual input with tactile and verbal input, and utilizing the child's strengths of detecting high contrast colors and motion (Good et al., 2001). This study worked on increasing the use of Jacob's residual vision by simplifying the outside environment. The outside environment was simplified through turning off the overhead light and taking down posters on the wall. The researcher also gave verbal prompts and used activities with high contrast colors and motion. One way in which this study differed from the CVI literature was Jacob's increased interest in more complicated images over simplistic images. For example, he enjoyed the activities with many multi-colored dots more than the blank screen on which one image appeared one at a time. The observation of Jacob's interest in increased visual information and stimulation is contrary to the traditional belief that a simplification of the visual stimuli is beneficial for individuals with CVI (Groenveld et al., 1990).

During phase 1 the number of activities per session varied based on Jacob's attention and motivation. During some sessions only one activity from each program was done and during other sessions three activities from one program and two from the other program were completed. If Jacob appeared uninterested in an activity, by looking away from the screen, the researcher directed him to the screen and modeled the activity. If he did not engage with the activity in five minutes a different activity was chosen. The researchers tried to rotate the activities to keep his interest. He typically completed different activities than the previous day, unless he had mastered most of the activities in that level. If Jacob was unsuccessful with multiple activities in a level, a previously mastered activity was used to increase his motivation and confidence. After Jacob was more engaged, the previously unsuccessful activities were reattempted, typically with more success. There was a notable difference in Jacob's facial expressions and movements when he was not successful with an activity. When Jacob was then able to complete an activity with success his demeanor would improve and his motivation increased. This increase in motivation then translated to greater success with the same activity that was previously too difficult for him. During the study, Jacob became discouraged when he was not having success just as his typical age peers would. When working with individuals with complex needs it is important to ensure that they experience success to increase motivation and maintain their moral through difficult tasks.

The researcher also tried to increase Jacob's attention and motivation using various strategies. Constant verbal encouragement and praise were given throughout the sessions. The researcher reminded Jacob of his success that day and in previous sessions and then prompted him to continue the task. When Jacob had success the researcher praised him and stated what he had done (e.g. "Wow, that was awesome! You made two blocks disappear"). This gave Jacob information about the success he was demonstrating from a verbal source, in addition to what he was seeing on the screen. Furthermore, giving specific verbal prompts paired with a visual prompt was beneficial for Jacob. Telling him exactly what part of the screen to look at while pointing to that area was helpful, especially when he was learning a new skill. These verbal prompts contained information about where to look and how long he needed to look. He needed feedback from multiple sensory sources, both visual and verbal, to receive the most benefit. This reflects the CVI literature that discusses the importance of giving the individual with CVI information from multiple sources (e.g. verbal, tactile) to increase his/her understanding of the information (Groenveld et al., 1990).

Finally, the environment and positioning of the participant was very important for success throughout the study. The low lighting source from behind the participant brought his attention to the screen and not to a different light source. Achieving the ideal positioning of the screen was difficult in the initial sessions, due to Jacob's visual field deficits. The screen needed to be left of midline as he had right visual field deficits; however, he could not calibrate to the device so there was less flexibility in placement of the screen. The eye tracker software was used during each session to assure that Jacob was within a good distance for use and the device could see at least his left eye.

EEG. An EEG was completed during the first phase of this study. The results from the EEG were inconclusive as to whether or not Jacob recognized the target stimuli. A significant difference was demonstrated by the lack of overlap between the confidence intervals of the target and non-target stimuli. There was a significant difference seen in Jacob's EEG on some of the electrodes between 0.4 and 0.5 seconds. For this type of task, it is expected that the significant difference appears earlier. A difference at the 0.4-0.5 latency is typically representative of a cognitive processing stage. The results are inconclusive for this task as the significant difference did not appear where expected. However, there was a significant difference across trials which indicates a consistent response. Jacob was having a neural response to the presented images and words, but due to the lack of current research it cannot yet be determined what the response represents.

Phase 2 Communication

Tobii Communicator 4 was introduced when Jacob was at level 3 of Look to Learn and level 4 on Sensory EyeFX. At this point Jacob demonstrated a consistent ability to dwell to select, was accessing a greater area of the screen, was beginning to track objects and could interpret more visual information as the screens became more complex in the eye gaze training software. When Tobii Communicator 4 was first introduced in sessions 34-39 a specialized communication board was used. In session 39 Jacob transitioned to the Sono-flex user to determine if he could access a premade user and if his utterances would increase. He expressed enjoyment through smiling and laughing when the Sono-flex user was introduced and he was able to access it immediately. He produced seven different utterances during the first trial with the Sono-flex user. It was decided to exclusively use the Sono-flex user for the remainder of the study as he could access it and it provided him with a greater variety of vocabulary. It was important to give Jacob access to the least restrictive user and vocabulary set that he was able to access. With the Sono-flex user he could access core vocabulary, create multiple word phrases and communicate for a variety of purposes. If the Sono-flex user was not attempted, Jacob would not have been able to produce the same variety of utterances or communicate for a variety of purposes as he did in this study. Sono-flex was not introduced initially because of skepticism of his ability to access the board. The symbols have little contrast and are close together increasing the chance of the crowding effect. However, Jacob clearly demonstrated his ability to use the Sono-flex board. He also showed excitement and increased motivation from the specialized board. This demonstrates the importance of presumed competence. The less restrictive option should always be attempted, even if it is unlikely that the individual will succeed.

Jacob produced a variety of different utterances during phase 2, despite his lack of formal communication prior to this study. In phase 2 he commented, initiated interactions, answered questions, made choices, asked questions and made requests/commands. He explored many different pages within the Sono-flex user and navigated to those pages independently many times throughout the study. This independent navigation required him to dwell on the icon for the page and then on the icon within the page he wished to use. This showed purposeful intent for communication. He also answered questions relevantly and his comments were on topic, indicating that his utterances were not random selections. Toward the end of the study Jacob began to combine two or more icons to make a phrase. He produced 11 two-word phrases and 1 three-word phrase. These combinations were not always immediate and he often needed several minutes to select the second icon for his phrase. The phrases were logical and relevant to the conversation. Examples of these utterances are found in the Appendix A.

Jacob was able to access the Sono-flex user effectively, even with his barrier of CVI. As previously mentioned this was surprising as the Sono-flex user does not use high contrast colors or motion, which have been traditionally thought of as essential elements when working with individuals with CVI (Good et al., 2001). The icons are on white backgrounds with a light colored boarder around each icon. All the icons are stationary and the only change in screen occurs when a new page is selected. Based on this knowledge of CVI and his previous vision evaluations, it was assumed that he would need icons that were at least 2 x 2 inches and had high contrast backgrounds. At the beginning of this study the hope was that Jacob simply be able to access the device and use specialized boards to make simple requests. Jacob exceeded that expectation in this study. He was able to effectively communicate using a premade user of Sono-flex. He progressed from no formal means of communication for the past 14 years, including no yes/no response, to being able to create a phrase with multiple symbols and communicate for a variety of purposes. Jacob serves as an excellent reminder to presume competence and to find a reliable means of communication for any individual, no matter his/her presumed skills.

Jacob's number of utterances varied during each session. This variability could be based on a number of factors, the most probable being alertness. Jacob produced more utterances when his session was earlier in the day and he was more alert. Due to scheduling difficulties, Jacob's sessions had to move to 5:00 pm during his last 10 sessions. These sessions then occurred after he attended school and Boys and Girls Club and before he received his evening meal. His energy level was noticeably decreased and some days he arrived asleep. During these sessions he produced less utterances. When his sessions could occur earlier in the afternoon around 4:00pm, he was much more alert and produced more utterances in the session. It is important to consider the energy level of individuals with complex needs when teaching a new skill or completing a task that requires increased concentration. It was easier for Jacob to attend and remain motivated when he was more alert and at an increased energy level. However, despite his decreased alertness and energy in the last 10 sessions he still communicated during every session. This demonstrated that Jacob's desire to communicate was strong and he had developed his eye gaze skills to the point where he could access the screen, even with decreased energy and alertness.

There are multiple aspects of the vision of individuals with CVI that would be thought to be detrimental when using the Tobii I-12 device. Individuals with CVI often have visual field deficits which would disable them from seeing part of the screen. They often have short visual attention spans which would make it difficult for them to take in the information on the screen and dwell to select. Finally, they are thought to experience a crowding effect as they are observed to bring objects close to their face so they can see one image at a time (Good et al., 2001; Groenveld et al., 1990). This is problematic when using a communication board with multiple icons placed closely together on a screen. Despite these barriers of CVI, Jacob was able to use a standard user on Tobii Communicator 4. He has documented visual field deficits affecting much of his vision, yet he was able to access the whole screen of the Tobii I-12 when it was placed just left of midline. We have evidence of this from the heat maps that cover the entire screen. He was able to find and use words on the communication software that were relevant to the conversation. In order to select a word he had to scan the screen for an appropriate word and hold his gaze on that word for 300 milliseconds, which required extensive visual attention. He also was able to separate out each symbol and find its location to select it. This would be very difficult if he experienced the crowding effect as the symbols have the same background and are placed closely together. There were several visual skills that Jacob demonstrated in this study which contradict the literature on what is typical for individuals with CVI. Further investigation is needed to determine if eye gaze training can improve the visual skills of other individuals with CVI.

Clinical Implications

The results of this study demonstrate that there is a possibility for individuals with severe disabilities and no apparent reliable access method, to access communication. It also demonstrates that an older child, who has never had access to communication, can learn to communicate when given access and training. We hope that this study inspires clinicians to try eye gaze training with individuals with CVI and limited communication skills. The study consisted of 58, 30-minute sessions that occurred over the course of seven months. The study was not as intensive as it was originally intended, which reflects the realities of working with individuals with multiple disabilities. This is a realistic treatment schedule for most settings and is easy to administer once the clinician has access to the device and training programs. This study demonstrated that an individual with multiple disabilities, including CVI, was able to gain eye gaze skills and maintain those skills between sessions and eventually learn to communicate.

This study is promising for individuals with CVI and multiple disabilities that impact their ability to communicate. CVI affects a significant population and these individuals need access to communication. The participant in this study continues to work on his eye gaze and communication skills at the clinic and has sought funding for a Tobii I-15 device. He is now able to communicate his wants, needs and desires, through the device which he has never been capable of doing before. Further research is needed on eye gaze access for CVI so that more individuals can access communication to meet their daily needs.

Limitations

This is a case study design with one participant so the findings cannot be generalized to others. There was also no control for outside variables, such as changes in his routine at school or other therapy. However, his caregiver reported no change in outside therapy or regimen during the study.

Conclusion

Through the use of eye gaze training programs and AAC intervention, Jacob progressed from having restricted eye gaze skills and no formal means of communication to using eye gaze access to communicate on a Tobii I-12 device. He expanded his eye gaze skills including the development of dwell to select, accessing the whole screen and tracking objects on the screen.

He also learned to use a standard user on communication software and held conversations with the researcher. He communicated for a variety of purposes and began creating multiple word phrases. Despite his diagnosis of CVI Jacob is using his eyes to communicate.

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Appendix A Examples of Utterances

Session 43

R- Researcher

J- Jacob

R: Do you like swimming?
J: Yes
J: It
J: Can
R: It can what?
R: It can. Are you talking about swimming? Swimming can?
R: Swimming can be fun
R: where do you swim?
R: you can swim at the beach, at the lake, at the pool.
J: Beach
R: That's hard water to swim in. I like to swim at the pool. But you like to swim at the beach?
J: Beach
R: Ok if you insist, you like to swim at the beach.
R: I believe you. We don't have a beach around here though.
R: Where did you swim today? (read options)
R: Your mom said you swam at school in the pool? Is that right? Where did you swim?
J: Bathroom
R: You swam in the bathroom? Or did you go to the bathroom?
R: There was a bathroom at the pool probably.
R: Do you want to read? Do you want to read the new book I have?
R: What else did you do today?
J: Drink
R: You had something to drink? Or do you want a drink?
J: Drink
R: You want a drink.
J: navigated to feelings page
J: Frustrated (teared up)
R: You're frustrated because you can't drink
R: I'm sorry buddy I can't give you something to drink?
R: What else are you feeling?
J: Home button to exit when I asked him what else he felt
R: I am going to make a little book for you? Will you pick some words for me that I can write a book about.
R: What do you want to talk about?
J: Airplane
R: You want to write a book about airplanes.
J: Can not
R: You can do it. I will help you.
R: Let's talk about airplanes.
R: What do air planes do? (read words)

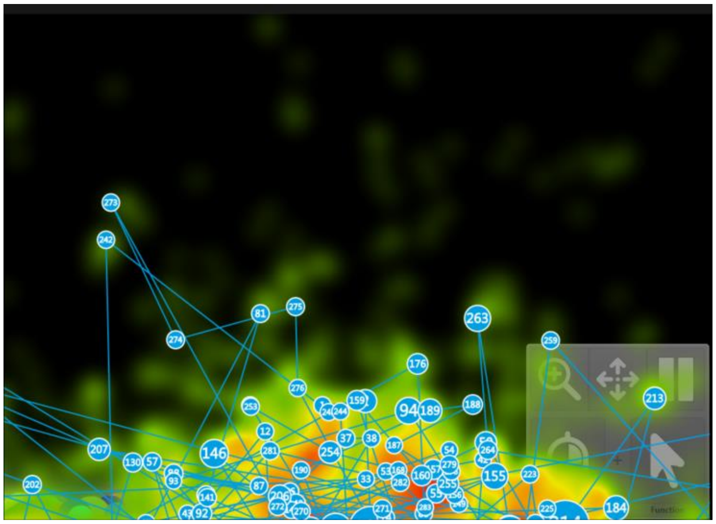
J: Help
R: Airplanes help. Is that what you meant to say?
R: Or should I help you
R: Look airplanes fly.
R: What do airplanes do?
J: Jump
R: Airplanes jump?! I don't think so!
R: What else do airplanes do?
R: You are doing such a good job focusing. So close.
R: Good job look at it just a little bit longer (looking at fly)
R: What do airplanes do?
J: Jump (next to fly)

Session 43

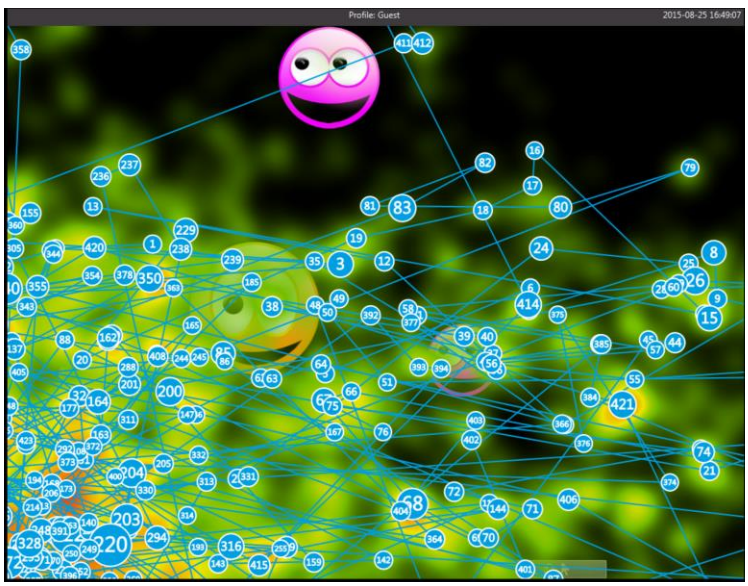
R: Hey I brought a new book if you want to read. Otherwise we can just chat.
J: With these
R: With these?
R: What? Look X here are somethings we can talk about.
J: Airplane
R: Do you like to watch the airplanes?
R: I like to fly on airplanes.
R: Have you ever flown on an airplane?
R: I have. I would say yes (indicating the icon)
R: Have you flown on an airplane?
J: Yeah
R: Yeah you've flown on an airplane before! That's awesome!
R: Did you fly here or somewhere else?
He opened people page
R: Did you go with someone on the airplane?
R: Who did you go with?
J: Sister
R: You went on the airplane with your sister?
R: Yeah, Just you two?
R: I just flew on an airplane by myself. I wish my brother was there.
R: Did you play this weekend?
R: What did you play with this weekend?
J: Book
R: You read a book this weekend or do you want to read a book right now?
R: If you want to read the book say reading.
J: I can (two word)
R: you can? You can read it?
R: what do you mean I can…
J: And (initiation)
R: And? Who can?

J: Enemy
R: Enemy? Do you have an enemy?
J: If you want to get out of this page you can select back up here.
He navigated to TV
R: Do you want to watch TV? If you do say watch.
J: Character
R: Is there a character that's an enemy?
J: Character
J: Volume down
R: Do you want it down? There I turned it down.
J: Character
R: Do you want to watch? I'll pull one up.
R: Do you want to watch a video or go back?
R: What do you have on? What is this?
J: Necklace
R: It's a necklace? Is that right? It is near your neck.
He navigated to time.
R: What do you want to tell me about time?
R: Right now we are in October and at the end we have Halloween
R: And then in November we have Thanksgiving, And then in December we have Christmas and then January is New Years eve.
R: I like October.
R: What month do you like?
J: Yesterday
J: Afraid
R: Yesterday you were afraid? Or are you afraid of Halloween?
R: Does Halloween scare you? Are you afraid?
R: Are you? Tell me yes or no.
J: No
R: You were just fooling me!
R: Good I'm glad you're brave
R: I wonder what you're going to be.
R: Is what you're going to be on here?
J: Dog
R: You're going to be a dog?
J: Tomorrow
R: You're going to be a dog tomorrow or you're going to see a dog tomorrow?

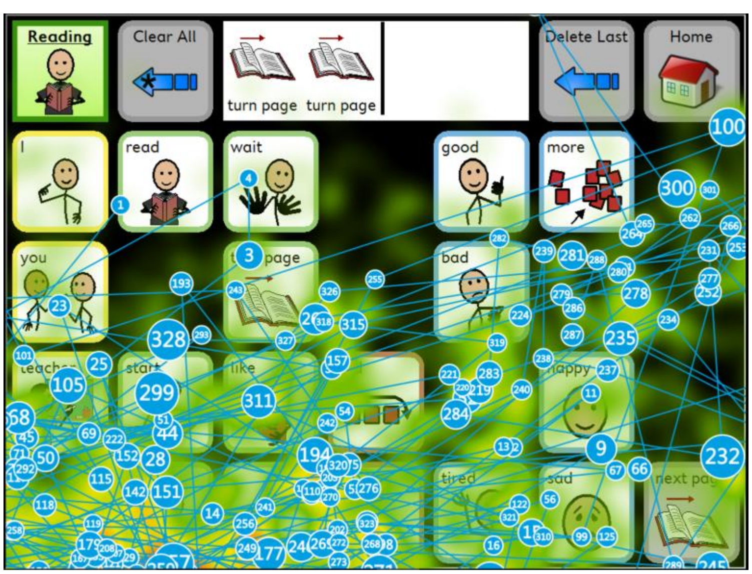
Appendix B Gaze Plots and Heat Maps



Gaze Plot Session 8



Gaze Plot Session 23



Gaze Plot Session 51